

# Digital Camera Traffic Accident Investigation System

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## INTRODUCTION

The traditional method used by law enforcement agencies to measure the scenes of traffic accidents is the coordinate method, which involves establishing a base line and measuring perpendicular-off-set distances to points of interest. The measurements are usually taken with a 100-foot tape, or a distance-measuring wheel. In many cases, use of the coordinate method requires that traffic lanes be closed for an hour or more in order to allow the investigating officers to make the measurements needed to adequately document the accident scene. The lane closures often increase traffic delay and the risk of secondary collisions. Diagrams of the accident scenes are prepared manually from the measurements.

In recent years, some law enforcement agencies have started using total station surveying equipment to document traffic accident scenes. This system features an electronic theodolite equipped with an internal electronic distance-measuring device and a built-in microprocessor, which make it possible to automatically measure and record distances and angles to a reflector placed at the points of interest at the accident scene. The survey data are recorded in an electronic file, which is processed in the office to generate an accurate, scale diagram of the accident scene. Experience with the total station surveying system indicates that about twice as many measurements can be taken in half the time required with the conventional coordinate method. Also, it reduces the number and duration of lane closures required to measure the accident scene, which in turn reduces the delay to traffic, the potential of secondary accidents, and the risk to the investigating officers.

Unfortunately, the equipment and training required by the total station surveying system are beyond the means of many local law enforcement agencies. However, advances in digital camera technology have made it possible to develop an affordable traffic accident investigation system, that provides the time-savings benefits

of the total station surveying system and yet requires minimal training and expense.

In August 1996, the University of Nebraska-Lincoln (UNL), in cooperation with the Nebraska Department of Roads (NDOR) and the Omaha Police Department (OPD), initiated a project to evaluate the application of digital camera technology for traffic accident investigation. The effort involved developing a digital camera traffic accident investigation system (DTAIS) and comparing it to the coordinate and total-station-surveying methods of accident investigation. The project was funded by the Federal Highway Administration (FHWA) Priority Technology Program with matching funds provided by the NDOR, OPD, and UNL.

This paper describes DTAIS and its evaluation. The results of field tests comparing it with the conventional coordinate and total-station-surveying methods of accident investigation are presented. The potential for its implementation by law enforcement agencies is discussed.

## BASIC PRINCIPLE

A camera system projects the three-dimensional view of the real world onto its image plane. Every point in the field of view is mapped to a unique point on the image plane. The basic problem is to deduce the mapping accurately enough by locating the projections onto the image plane of a small number of known points in a calibration step. Once determined, the mapping enables the real-world locations of other points in the image to be determined.

The general solution to this perspective-projection problem is well-documented in the photogrammetric literature. The basic approach involves bringing the real-world reference frame into correspondence with the camera reference frame by a sequence of rotations along the three axes of the real-world reference frame. Having thus found a representation for a three-dimensional point in the camera reference, and assuming a pinhole camera, the projection of the point in the camera image plane in terms of the camera lens focal length can easily be determined.

## FUNCTIONAL REQUIREMENTS

A meeting was held with a panel of experts to define the functional requirements of traffic accident investigation, which provided the basis for the design and evaluation of the system. The panel included representatives of law enforcement, accident records, vehicle insurance, accident reconstruction, and traffic engineering.

The functional requirements addressed such factors as: (1) degrees of measurement accuracy and precision; (2) types and numbers of measurements; (3) accident report requirements; (4) time

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**FIGURE 1** Digital camera.



**FIGURE 2** Rod.

constraints; and (5) manpower and equipment limitations. The following is a summary of the functional requirements used to design and evaluate the system:

1. Types of measurements: The system must be able to measure three-dimensional surface coordinates.
2. Range of measurements: The system must be able to operate within the field of view up to a distance of 150 feet from the camera. Larger accident scenes can be measured from multiple camera setups. The system must also be able to measure points located off the roadway as well as on the roadway.
3. Accuracy of measurements: The system must have at least the same accuracy and precision as the manual system currently used by OPD, which is about  $\pm 1$  foot.
4. Number of measurements: The system must be able to store the data for up to 50 measurements.
5. Records: The system must generate an accident report and diagram in the format used by OPD.
6. Cost: The system cost should not exceed approximately \$1,000 for field equipment and \$5,000 for office equipment.
7. Operating conditions: The system must function day and night. However, it should first be developed to work in daylight. Night-

time conditions should be considered after the system has been demonstrated to work in daylight.

8. Ease of use: The operation of the system should require only one person.
9. Training requirements: No more than 2 hours of training should be required for the field procedures, but the office procedures may require up to 40 hours.
10. Speed: The system should provide a 50-percent reduction in the time spent measuring distances at the scene.
11. Portability: The system must be small enough and rugged enough to be carried in the trunk of an OPD patrol car.

## SYSTEM

The DTAIS system consists of the following components:

1. Kodak DC-120 digital camera with 1280 x 960 resolution, a 16-degree field of view, automatic focus, and automatic shut off
2. Tripod equipped with a leveling device on which the camera is mounted
3. Extendible, 6-inch x 7-foot, red-and-white stripped rod equipped with a flip-chart with letters and numbers for identifying measurement points.

The camera is shown mounted on the tripod in Figure 1. The rod is shown in Figure 2.

## FIELD PROCEDURE

The field procedure involves two basic steps: (1) camera setup and (2) measurement. The camera is positioned at a location and orientation so that all points of interest (i.e., evidence points and roadway features) are within the field of view. Two reference points are selected within the field of view to provide a frame of reference for the measurements. The reference points should be well-defined landmarks at the accident scene, such as manholes, fire hydrants, or utility poles. The two points define a baseline to which the locations of the points of interest are referenced. The camera is then used to obtain images of the rod placed vertically at all points of interest including the two reference points.

In some cases, all of the points of interest cannot be imaged from one camera view, because the accident scene is too large or the view of some points is obstructed. Therefore, multiple camera views are required. In order to relate all of the measurements to the frame of reference established from the first view, it is necessary to connect a subsequent view to the previous view by imaging at least two points in the subsequent view that were imaged in the previous view.

## ACCIDENT REPORT PREPARATION

The accident report is prepared with the DTAIS software. The software is written in C++ using Microsoft Visual C++ and designed to run on Windows 95. It requires a Pentium or better processor with 16 Mb of memory and enough disk space for the image files.

The files of the images of the points of interest taken at the accident scene are input to the program. Thumbnails of the images are displayed on the working screen as shown in Figure 3. The images are selected one by one from the thumbnails for processing. When an image is being processed, it is displayed in the main portion of the screen below the thumbnails. The user clicks on the center of the rod with the mouse and the 5-foot reference interval (i.e., from the top of the upper red strip to the bottom of the lower red strip) is



FIGURE 3 Working screen.



FIGURE 4 OPD officers marking evidence points at mock accident scene.

automatically located and its image coordinates determined. The Record Target button activates a dialog box which enables the user to enter a narrative description of the point and store the information along with the point's image coordinates. After all of the images have been processed, the user clicks on the  $\Sigma Y$  icon on the tool bar, which causes the program to compute the real-world coordinates of the points and generate a table containing the descriptions and real-world coordinates of the points. In addition, an AutoCAD file is generated, which contains the points plotted to scale. The program output includes the tabulated description of the points and the AutoCAD plot.

## EVALUATION

The evaluation of the DTAIS system was conducted in two stages. In the first stage, the system was used to measure three mock accident scenes created at the UNL Midwest Roadside Safety Facility. These scenes were the results of full-scale crash tests of bridge railings and guardrails conducted at the facility. After each crash test, OPD officers identified and marked the evidence points with spray paint in accordance with their normal procedures as shown in Figure 4. Then they measured the points using both the coordinate method and DTAIS. Two members of the Kansas Highway Patrol Critical Highway Accident Response Team participated in the measurement of the third mock accident scene. They measured the mock accident scene using their total station surveying equipment as shown in Figure 5.

DTAIS was compared to the coordinate and total station surveying methods in terms of measurement accuracy, time required, and degree of difficulty. It was determined that DTAIS met the functional requirements specified by the expert panel, except that its operation required two officers instead of one. However, the total station surveying method requires two officers and the OPD typically uses two officers to measure an accident scene with the coordinate method. Therefore, it was concluded that the system was ready for field testing by the OPD.

In the second stage of the evaluation, the OPD used DTAIS to investigate accidents occurring in Omaha. The officers used both the coordinate method and DTAIS to measure each accident scene. In addition, they prepared their routine accident report and an accident report using DTAIS software. Members of the study team accompanied the officers to the accident scenes to document the investigation procedures and provide technical support. The documentation of each accident scene investigation included a comparison of the coordinate method and DTAIS with respect to measurement agreement, field measurement time, report preparation time,



**FIGURE 5** CHART officers measuring mock accident scene with total station.

level of effort, and degree of difficulty. Problems encountered and feedback from the officers were noted. A total of four accidents were investigated.

The results of the field investigation indicated that the DTAIS met the functional requirements specified by the expert panel. In addition, the field investigation experience resulted in a number of refinements to the system that will significantly improve its implementation. These refinements included: (1) revisions to the Operating Procedures Manual to provide camera location guidelines and clarify the explanation of base lines and reference points; (2) revised calibration procedure, which eliminates the calibration step for each camera position and replaces it with calibration at the police station; (3) modifications to the software designed to make it easier to use and more compatible with current OPD practices and terminology; and (4) development of an extendible rod which will facilitate the field procedures and improve accuracy.

The field investigation also identified some barriers to implementation of the system which must be addressed. Implementation of the system by OPD requires that these barriers be eliminated. The barriers and the actions currently underway to overcome them are summarized in Table 1.

## CONCLUSION

The evaluation of the DTAIS has demonstrated the feasibility of using digital photography for the investigation of traffic accidents. This technology can provide the necessary degree of accuracy and substantial savings in the time required to measure accident scenes and generate accident reports. The UNL, in cooperation with the NDOR, OPD, and FHWA, are refining the system to address the implementation barriers that were identified. It is anticipated that this effort will be completed by the end of 1998.

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**Table 1** Barriers to the Implementation of DTAIS

Implementation Barrier	Action
Software too complicated. Too many camera setups.	Improve software user interface. Increase camera's field of view by zooming out and use camera with higher resolution. Also, investigate the feasibility of adding a GPS unit.
Nighttime operation.	Improve software to include automatic interval finder for nighttime images.
Operation during inclement weather.	Investigate the feasibility of weatherproofing the camera.
3D measurements.	Improve software to provide 3D analysis.
Cumbersome method of tagging ID and description to points.	Investigate the feasibility of keying point ID and description directly into camera.
Incomplete accident diagram.	Improve system to enable generation of complete accident diagram including evidence points and roadway features.
Limited awareness of technology.	Make presentations describing system to law enforcement agencies and association meetings and publish articles describing system in law enforcement journals.

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